

THURSDAY, JANUARY 30, 1879

THE ART OF SCIENTIFIC DISCOVERY

The Art of Scientific Discovery, or the General Conditions and Methods of Research in Physics and Chemistry.

By G. Gore, LL.D., F.R.S. (London: Longmans, Green and Co., 1878.)

IT is not easy to say when scientific research, using the expression in its strictest sense, was first commenced. M. Libri remarks: "Les recherches des Pythagoriciens sur les vibrations des corps, sont les plus anciennes expériences de physique qui soient parvenues jusqu'à nous." Archimedes must certainly be credited with some knowledge of research; and to a lesser extent Ptolemy the astronomer, and Hero, of Alexandria. But, as a matter of fact, experimental researches in physics were not made before the epoch of Galileo, nor in chemistry before the epoch of Lavoisier. The discovery of new methods of mathematical analysis on the one hand, and the invention of instruments of precision on the other, were necessary forerunners of the development of research. Moreover, the advocacy of the abandonment of that blind reverence for authority which had retarded the progress of the sciences for many centuries, tended in the same direction. In this respect, whatever we may say of Campanella, Nizolius, Telesius, and others, our own Francis Bacon did more true service than any of his predecessors; and we must always regard his writings as the most potent engine concerned in the overthrow of Aristotelianism, Scholasticism, and the method of pure logic, and in the substitution of the experimental method blended with just logical induction and deduction.

Mr. Gore, whose own devotion to experimental research well entitles him to act as an interpreter of the art of scientific discovery, has in the course of sixty chapters of condensed matter discussed the various lines of thought and of action which converge towards that bright central focus in which new truths lie hidden. His object has been to describe the nature, the methods, and the conditions of success of original scientific research; to point out the causes of failure, the mental and manual discipline by which they may be overcome; and the special modus of thought by which we may hope to ascend from the known to the unknown.

With this object in view he has divided the work into five parts, the first of which contains a general view of the subject:—the nature of scientific ideas, terms, and beliefs, the criteria of scientific truth, and the great principles of science. In the second part he has discussed the general conditions of scientific research:—the starting points, chronological order of discovery, importance of qualitative knowledge, and necessity of classification. The third part is devoted to the personal preparation for research; the fourth to the actual working in original research; and the fifth to special methods of discovery. This latter is divided into ten parts, which treat respectively of discovery:—

1. By extending undeveloped or neglected parts of science.
2. By the use of new or improved instruments.
3. By the investigation of likely circumstances.

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4. By devising hypotheses and questions, and testing them.

5. By means of new experiments and methods of working.

6. By means of additional, new, or improved observations.

7. By classifying and comparing known truths.

8. By means of study and inference.

9. By means of new or improved methods of intellectual operation.

10. By means of calculations based upon known truths.

In the discussion of these subjects, the history of various scientific discoveries is traced, and we are not only brought into contact with the investigator's particular train of thought throughout all the steps which led up to the discovery, but we are often taken into the minuter labyrinths and shown the many collateral ideas which were evoked during the course of the research. The influence of previous discoveries upon the main subject at issue is also developed, so that we gain important information regarding the history of the sciences, while at the same time we are becoming acquainted with the art of original research.

In that portion of the work which relates to method, we are not surprised to find that the author has often quoted Lord Bacon. In fact, Mr. Gore's style is sometimes thoroughly Baconian. So penetrated is he by the spirit of the "Novum Organum," that he sometimes unconsciously embodies its aphorisms with his own; for example, when he says: "Science is the interpretation of nature, and man is the interpreter. Original research is the chief source of new scientific knowledge." His work may almost be called a nineteenth century continuation of the second book of the "Novum Organum"—a sort of *newest organum*. He also quotes pretty frequently the "History of the Inductive Sciences," and sometimes the "Novum Organum Renovatum," with which the "Art of Scientific Discovery" has many points of contact. We are surprised to find Descartes so rarely alluded to, albeit portions of the work relating to Method are thoroughly Cartesian in spirit. Here, for example, is an excerpt from the *Regulæ ad Directionem Ingenii*, which we recommend to Mr. Gore's notice for the second edition:—"By method I understand rules certain and easy, such as to prevent any one, who shall have accurately observed them, from ever assuming what is false for what is true, and by which with no effort of mind uselessly consumed, but always by degrees increasing science, a person will arrive at a true knowledge of all those things which he will be capable of knowing." Also we commend to his notice the answer to *Quid sit Cogitatio* ("Principia," Pars 1, ix.); and to that very notable assertion ("Principia," Pars 2, xxiii.), *Omni materia variationem, sive omnem ejus formarum diversitatem pendere à motu*.

Early in the work Mr. Gore points out a fact which we too seldom recognise. "Original research," he writes, "is not a science; it is not a collection of laws. It is an art, because it is composed of rules which must be followed. It is the method of finding new truths by means of study, observation, travel, or other means." Now although we think that an investigator must be born and cannot be made, and that no one can frame his methods upon hard

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and fast lines of thought or operation, we are quite of opinion that those who make original researches, or are about to make them, may gain much from orderly methods of manipulation, and a knowledge of the right application of logical inference. Bacon attempted to describe such methods in his "Inquisitio de Forma Calidi," and failed, because at that time there did not exist a sufficient basis upon which to found an exhaustive experimental treatment of the subject.

Two interesting chapters in the first part of the book are devoted, the one to the facts and propositions in science, and the other to the criteria of scientific truth. We are reminded herein of an interesting treatment of these subjects in the "Philosophie Méthodique" of M. de Strada, to which we venture to refer our author.

Among the conditions of success in research Mr. Gore very justly enumerates enthusiasm. Of this he quotes several examples. Becher, of Phlogiston fame, after speaking of the chemists as "a strange class of mortals impelled by an almost insane impulse to seek their pleasure among smoke and vapour, soot and flame, poisons and poverty," adds: "Yet among all these evils I seem to myself to live so sweetly, that may I die if I would change places with the Persian King!" The fascination of original research is undoubted, the enthusiasm which it sometimes inspires is unbounded. We remember an instance of a schoolboy who seriously proposed staying at school for several days at the beginning of the Christmas holidays, when "home, sweet home," is doubly sweet, in order to continue a research. And truly, were it not for the enthusiasm which it engenders, the amount of original work done in the world would be much less than it is, seeing that it is usually accompanied by numberless vexations and disappointments, and that it requires unwearied application and perseverance, joined to the possession of an undaunted spirit.

Of Mr. Gore's work as a whole we may say that it exhibits great industry in the collection of facts and a considerable amount of logical acumen in their discussion. Perhaps, however, the arrangement might be simplified. The mass of matter to be digested is so great that any increased modes of classification of the subjects that could be adopted would add to the value of the book. This could best be effected by numbering the paragraphs; by adding marginal references giving the gist of each paragraph, and by making some of the chapters more aphoristic in character. These changes could be easily effected in a second edition.

G. F. RODWELL

LEISURE-TIME STUDIES

Leisure-Time Studies; chiefly Biological; a Series of Essays and Lectures. By Andrew Wilson, Ph.D., F.R.P.S.E., &c. With numerous Illustrations. (London: Chatto and Windus, 1879.)

THIS volume of Essays and Addresses does not profess to contain anything new, either in the way of observation or theory. Neither is the author's style sufficiently brilliant, or his treatment of the subjects sufficiently original to raise them much above the level of the average lectures of a well-informed naturalist. They will, however, afford some useful and interesting

information to the general reader, and may serve to attract attention to the question of the introduction of biology into ordinary education. This is the special subject of the first address, which, however, though somewhat lengthy and profuse, does not attempt to grapple with the difficulty of finding competent teachers of biology for *all* our schools. It is indeed suggested, that "the amount of knowledge required to pass even the primary stage of the biological subjects, in the government examinations, held under the auspices of the Science and Art Department," should fit its possessor for imparting elementary instruction in biology. But we greatly doubt whether the examiners would be of this opinion; and we rather think it would be a distressing sight to witness a teacher, whose whole knowledge of the subject was derived from a course of study just sufficient to enable him to pass such an examination, exposed to the questions of a lot of intelligent country boys and girls, whose practical acquaintance with native plants and animals was far more extensive and accurate than his own. If biology is to be taught in schools it must not be by the regular school-teachers qualifying themselves by a few months' training in London, but by the employment of good naturalists to give lectures, demonstrations, and out-door excursions to all the schools of a district in succession.

In the succeeding address, on "Science-culture for the Masses," too much stress is laid on the teaching of science as "a pleasant system of mental gymnastics." This seems to us altogether a wrong ground to go upon. Science is not to be taught in order to strengthen the mind to do something else by and by, but because it opens the mind to a more adequate conception of the universe in which we live, and is in itself, truly, the knowledge which is power.

The lecture on "The Sea-serpents of Science" is interesting, both as giving a very fair summary of the most recent evidence on this subject, and as showing that the age of incredulity is past, and that naturalists are now prepared to admit that several distinct kinds of oceanic monsters probably exist, of which no single specimen has yet been obtained. Recollecting, however, the number of clever hoaxes to which this subject has given rise, we think that the newspaper account at p. 104, of the declaration before a Liverpool J.P., made by the master and crew of a merchant-ship, to the effect that they had seen a huge serpent twice coiled round a sperm whale, and a similar serpent with its head raised "sixty feet perpendicularly in the air," should not have been inserted as evidence without first ascertaining that such a declaration was actually made before the magistrate named. The trouble of writing a single letter would probably have been sufficient, and would have settled the preliminary question of whether the whole story, from beginning to end, was not a pure newspaper *canard*.

The article on "The Genesis of Life" repeats the now often-told tale of the fluctuations of opinion as to spontaneous generation, and will be interesting to those who have not read it elsewhere. Dr. Wilson tries his best to be impartial, and to place before his reader the exact position of the question at the present time. He acknowledges that "isolation" and "destruction" are the two great points of all experiments on the subject, and that if